PATHFINDER

HUMAN PERFORMANCE PROGRAM PLAN

February 1989

Office of Space Science
and Applications

National Aeronautics and
Space Administration

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Approved By:

______________________________ 3/9/89
Program Manager, Life Sciences Division — Date

Approved By:

______________________________ 3/9/89
Director, Life Sciences Division — Date

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Pathfinder Program Manager, Space Directorate — Date

Office of Space Science and Applications

National Aeronautics and Space Administration
Washington, D.C. 20546

FOREWORD

Pathfinder is a research and technology initiative by the National Aeronautics and Space Administration (NASA) which will strengthen the technology base of the United States civil space program and provide options for potential future space exploration missions. These missions may include an intensive study of the Earth, a return to the Moon, piloted missions to Mars, or the continuing robotic exploration of the Solar System. Pathfinder is managed by the NASA Office of Aeronautics and Space Technology, to advance critical technologies for these missions and ensure technology readiness for future national decisions regarding exploration of the Solar System. Pathfinder extends the technological foundation being established by the Civil Space Technology Initiative, which focuses on advancing a family of technologies for transportation to and operations in near-Earth orbit and supporting science activities. Pathfinder looks toward longer-term missions beyond Earth orbit and into the Solar System.

Four major thrusts of Pathfinder are Surface Exploration technology, In-Space Operations technology, Humans-in-Space technology, and Space Transfer technology. The Humans-in-Space thrust will provide the critical technologies to enable or enhance future long-duration piloted exploration missions. A key element of this thrust is the Human Performance Program, managed by the NASA Office of Space Sciences and Applications, Space Medicine and Biology Branch. The Pathfinder Human Performance Program focuses on specific technologies and other requirements needed to support human health, safety, and productivity on advanced space missions. Emphasis is placed on providing fundamental information in support of the use of artificial gravity, developing an understanding of the radiation threat and devising countermeasures, and providing the human factors and EVA information and technology base needed to enhance crew productivity.

This Program Plan describes the goals and objectives, management plan, technical approach, resources and financial management plan, facilities plan and technology transfer planning for the Human Performance element of Pathfinder. For additional information on the Human Performance Program, please contact:

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CONTENTS

List of Figures

List of Tables

SECTION 1

EXECUTIVE SUMMARY

1.1 Program Goals & Objectives

The long-term goal of the Pathfinder Human Performance Program is to specify technologies and other requirements needed to support human health, safety, and productivity on advanced space missions. In this program, emphasis will be placed on providing fundamental information in support of the use of artificial gravity, developing an understanding of the radiation threat and devising means to counteract this threat, and providing the human factors and EVA information and technology base needed to enhance crew productivity.

1.2 Organization and Management

The Human Performance Program will be planned and implemented in two broadly-defined phases. Phase I falls within the next five years, FY 1989 through FY 1993, and was budgeted in the FY 1989 Pathfinder Program Plan. Phase II is a projected phase, culminating in appropriate Human Performance requirements. Phase I will initiate studies in areas of artificial gravity, radiation, space human factors, and EVA. Phase II will build on the results of Phase I and involve the conduct of research investigations, demonstations, and cross-study integrations that will convert study results into mission requirements. Figure 1.1 provides the program work breakdown structure (WBS).

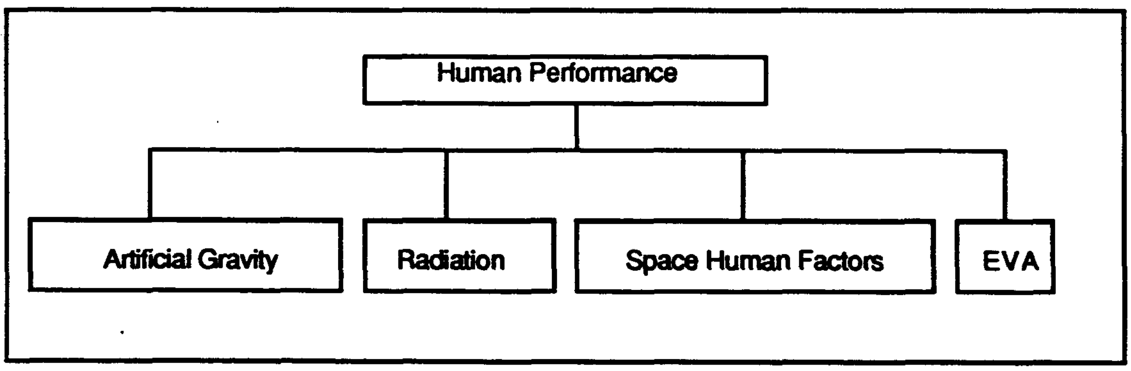

Figure 1.1 Pathfinder Human Performance Program Work Breakdown Structure

The Human Performance Program will be managed from the Office of Space Sciences and Applications, Space Medicine and Biology Branch (Code EBM), NASA HQ. The Program Manager assumes overall responsibility for the direction and execution of the program, for new program plans and for management and coordination of program elements. Work package managers, also located in the Space Medicine and Biology Branch, will have specific responsibility for the direction and implementation of work package activity. Ames Research Center, Johnson Space Center and other Centers will play key roles in the technical design, implementation and reporting of this program. Coordination of the Human Performance Program and other elements of Humans-in-Space will be through the Pathfinder Program Manager. Fig. 1.2 indicates the Phase I Human Performance Program management structure.

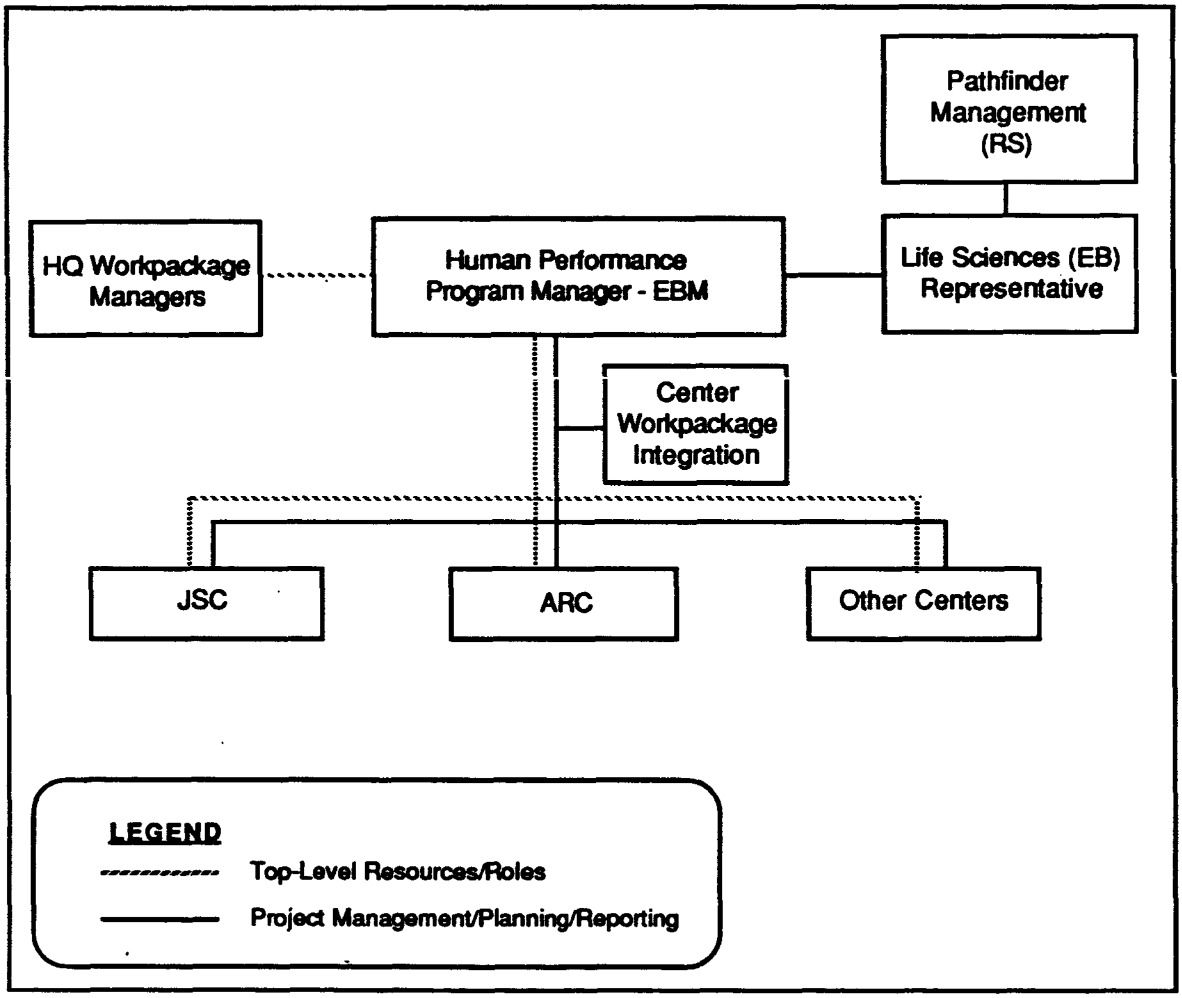

Fig. 1.2 Pathfinder Human Performance Program Management Structure

1.3 Schedule and Deliverables

By the completion of Phase I, preliminary requirements will be in place to guide the development of technologies for artificial gravity, radiation, space human factors, and EVA (assuming the availability of planned resources.) In the area of artificial gravity, descriptions of the effects of intermittent centrifugation and chronic rotation will have been made and determinations of the strategies for use of artificial gravity will be in place. In the radiation area, increased and more accurate information on Galactic Cosmic Radiation (GCR) and its biological effects and approaches for improving the detection and forecasting of Solar Particle Events (SPE's) will have been developed. In space human factors, preliminary requirements for crew organization and communication will be developed; mission analyses and preliminary habitability and human/machine guidelines will be assessed; and an analog testbed will be established. In EVA, preliminary physiological, environmental, and performance requirements for advanced systems will have been established.

During Phase II, the definition of all key Human Performance requirements will be completed. The direction of the artificial gravity work will be influenced by interactions with the Office of Exploration and commitments made at a national level, as well as by the results obtained in the Phase I research. As appropriate, the results of the artificial gravity research will be timed to support Phase C/D of the Variable Gravity Research Facility. In the radiation area, studies during Phase II will emphasize onboard alarm systems, forecasting technologies, and materials protection, both for transportation vehicles and in terms of the construction of radiation shelters from Lunar and Martian materials. For space human factors, Phase II will allow the completion of training requirements and human/automation guidelines definition, as well as the simulation of facilities and protocols developed during the program. During Phase II preliminary EVA requirements will be further evaluated and recommendations for advanced missions determined.

1.4 Resources

Resource requirements, including both funding and NASA workforce for the first five-years (Phase I) are provided in Table 1.1. Estimated funding levels required to support the Human Performance Program through Phase II are provided in Table 1.2.

RESOURCE REQUIREMENTS
HUMAN PERFORMANCE PROGRAM

RESOURCES	SCHEDULE (FISCAL YEAR)				
	1989	1990	1991	1992	1993
Funding ($,M)	2.125	2.2	9.0	11.0	13.0
NASA Workforce (WY/Year)	TBD	TBD	TBD	TBD	TBD

Table 1-1. PHASE-I

RESOURCES	SCHEDULE (FISCAL YEAR)				
	1994	1995	1996	1997	1998
Funding ($,M)	13.0	13.0	13.0	10.0	5.0
NASA Workforce (WY/Year)	TBD	TBD	TBD	TBD	TBD

Table 1-2. PHASE-II

SECTION 2

INTRODUCTION

2.1 Pathfinder Program Overview

Pathfinder is a National Aeronautics and Space Administration (NASA) initiative to develop critical capabilities to support the future of the U.S. civil space program. Pathfinder does not, in itself, represent a commitment to any particular mission. However through Pathfinder, NASA will develop a variety of high-leverage technologies that can be applied to a wide range of potential future NASA solar system exploration missions. Pathfinder is organized into four research and technology program areas: (1) Surface Exploration, (2) In-Space Operations, (3) Humans-In-Space, and (4) Space Transfer. The Human Performance Program is one of the four sub-programs in the Pathfinder Humans in Space technology thrust. Additional information on Pathfinder can be found in the Pathfinder Program Plan.

2.2 Document Purpose and Scope

This document is the Human Performance Program Plan. The purpose of this program plan is to provide the scope, content, and long-range plans of the Human Performance Program. The objectives of this document are: (1) to provided traceability to mission-derived technology requirements; (2) to specify the top-level work breakdown structure; (3) to define technical goals and objectives for the program and its major work packages; (4) to define the management responsibilities and accountability; (5) to establish resource allocations, and associated schedules, milestones, and deliverables; and (6) to document long-range Pathfinder Human Performance program planning.

SECTION 3

Human Performance
PROGRAM OVERVIEW

3.1 Mission Studies and Technology Requirements

NASA's planning for the future exploration of the solar system includes manned missions to the Lunar surface, to Phobos, Mars, or other destinations. The success of these mission will depend upon the ability of the human participant to perform effectively at each stage of the mission. Future missions will involve significantly greater distances, longer durations and greater crew autonomy than missions that have flown in the past. This means that flight crews on exploration missions will be subject to physiological and psychological stresses that could impact their welfare or the welfare of the mission. Among the more significant challenges to human health, welfare, and productivity are microgravity, radiation exposure, issues of space human factors, and extravehicular activity. In its attempt to adapt to microgravity, the body undergoes changes in the neurovestibular, cardiovascular, musculoskeletal, hormonal and immune systems. It is necessary to determine the requirements for maintaining the health of these systems over the long-duration of an exploration mission. In the radiation area, new challenges are posed when astronauts are exposed to prolonged periods of exposure outside the protection of the Earth's magnetosphere, as represented by an exploration mission. It will be necessary to establish appropriate radiation requirements and determine how, through shielding, warning systems, and other means, these requirements can be met. Long-duration and increased crew autonomy significantly increase the understanding needed of various aspects of Space Human Factors. Requirements need to be established in the areas of habitability, crew factors, human-machine studies and other areas that will render the space traveller healthy and productive on extended space missions. Requirements for extravehicular activity, especially as it involves construction and exploration tasks, will need to be determined for the various conditions of exploration missisons, i.e., 0-G and the reduced gravities of the Lunar and Martian surfaces. These requirements must include prebreathing regimes, health and workload monitoring and emergency return strategies.

3.2 Technology Assessment

The present state of requirements definition in the areas included under Human Peformance are severely limited, especially as they apply to anticipated long duration effects. Many physiological and psychological changes that can be compensated for over the short term have unknown impacts over longer periods. For instance, while it is possible to compensate for microgravity effects over a short duration mission through structured exercise regimes, these regimes are likely to prove ineffective or impratical over the long term. Similarly, medical and performance risks that can be reasonably accepted for a brief flight must be better understood and re-evaluated for long duration flight. It is likely that artificial gravity will be needed to offset changes to the various bodily systems. If so, it will be necessary to determine how much artificial gravity is required and how it should be to be employed. In order to ensure a high level of performance, it will be necessary to improve our understanding of how to comprise crews that can operate effectively while maintaining a high level of coherence and motiviation over the long term. In addition to duration effects, advanced missions will introduce conditions for which no baseline data exist, such as partial gravity effects (with both IVA and EVA implications) and the impact on crew performance of long transmission delays, and those for which insufficient baseline data exist, such as radiation exposure risks and effects beyond LEO. These various human performance variables must be reassessed in terms of representative mission parameters in order to establish requirements for future exploration missions.

3.3 Program Goals and Objectives

The goal of this activity is to specify requirements needed to support human health, safety, and productivity on advanced space missions. The specification of these technologies and requirements will necessitate that a program of research be implemented in selected, interrelated areas and that this research program be integrated, focused, and directed towards the production of a set of deliverables that collectively support the overall program goal.

Objectives of this program are:

1. To provide fundamental information in support of the use of artificial gravity and to develop the requirements to apply this information in support of long-duration manned missions.

2. To develop needed understanding of the radiation threat to human participants, to devise methods to minimize this threat, and to develop the requirements to protect the space traveller on exploration missions.

3. To provide the information and technology base requirements to enhance the productivity and maintain the safety of crews both during their mission and after returning to earth.

4. To develop the requirements and regimes associated with safe, productive, and efficient EVA activity.

5. To coordinate requirements definition in all tasks under the Human Performance element with related Research and Technology development in other elements of Pathfinder-HiS and with Code Z.

The goal of establishing human requirements for advanced space missions implies that the human must be protected from those aspects of the space environment that could pose a threat, while utilizing those aspects of the space environment that could foster his or her welfare. This dual approach will be emphasized in meeting the objectives of this program.

3.4 Technical Approach

The Pathfinder Human Performance Program will encompass a broad range of technical approaches, as appropriate to the level of understanding in the particular discipline area and the anticipated mission needs. The approach in each area will be tailored to the specific developmental needs of that area leading to the establishment of advanced mission data bases and the definition of requirements. Specific approaches are described in the Technical Plan, Section 5. Collectively, these approaches will include mission analysis, task analysis, mathematical modeling, workshops, simulation and baseline research.

SECTION 4

ORGANIZATION AND MANAGEMENT

4.1 Overview

The Human Performance Program is planned and will be implemented in two broadly-defined phases. Phase I falls within the next five years, FY 1989 through FY 1993, and was budgeted in the FY 1989 Pathfinder Program Plan. Phase II is a projected phase, culminating in appropriate Human Performance requirements. Phase I will initiate studies in aritificial gravity, radiation, space human factors and EVA. Depending on the level of maturity of the particular area, the product of this phase could be the specification of requirements or, in some cases, the ranging of requirements and the definition of further detailed, focused studies. Phase II will build on the results of Phase I and involve the conduct of those research investigations, demonstations, and cross-study integrations that will convert study results into mission requirements. The product of Phase II will be the ground-derived requirements and the definition of needed flight experiments.

4.2 Work Breakdown Structure

The Human Performance area is broken into the elements shown in Fig. 4.1, i.e., artificial gravity, radiation, space human factors, and EVA. Artificial Gravity includes rotation, duration and G-Loading studies; Radiation includes risk assessment, biological and physical dosimetry, solar particle event studies, operational dosimety, and countermeasures; Space Human Factors includes habitability, crew factors and human-machine issues. EVA includes those environmental, physiological and performance issues that impact the health and welfare of crew members while operating outside the protections of a vehicle or habitat.

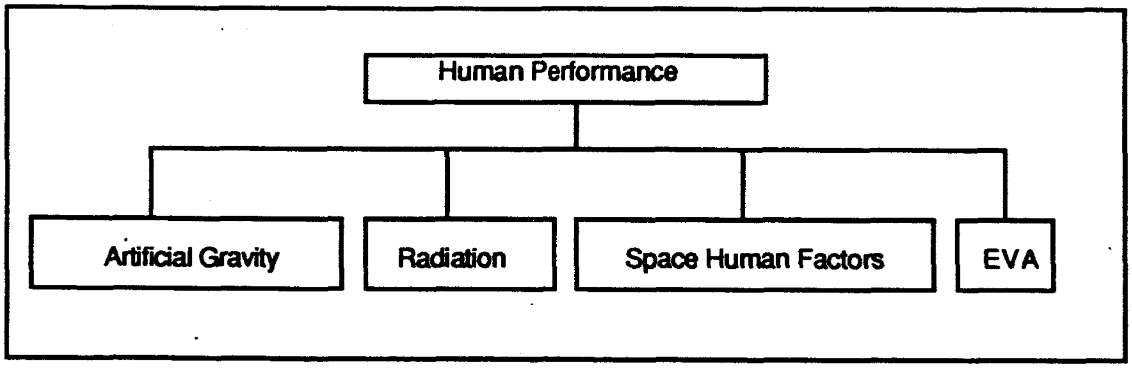

Figure 4.1 Pathfinder Human Performance Program Work Breakdown Structure

4.3 Management Structure

The management structure for the Human Performance Program is given in Fig. 4.2. The Human Performance Program Manager is located in the Office of Space Sciences and Applications, Space Medicine and Biology Branch (Code EBM) NASA HQ. The Program Manager assumes overall responsibility for the direction and execution of the program, for new program plans and for management and coordination of program elements. Work package managers, also located in the Space Medicine and Biology Branch, will have specific responsibility for the direction and implementation of work package activity. Ames Research Center, Johnson Space Center and other Centers will play key roles in the technical design, implementation and reporting of this program.

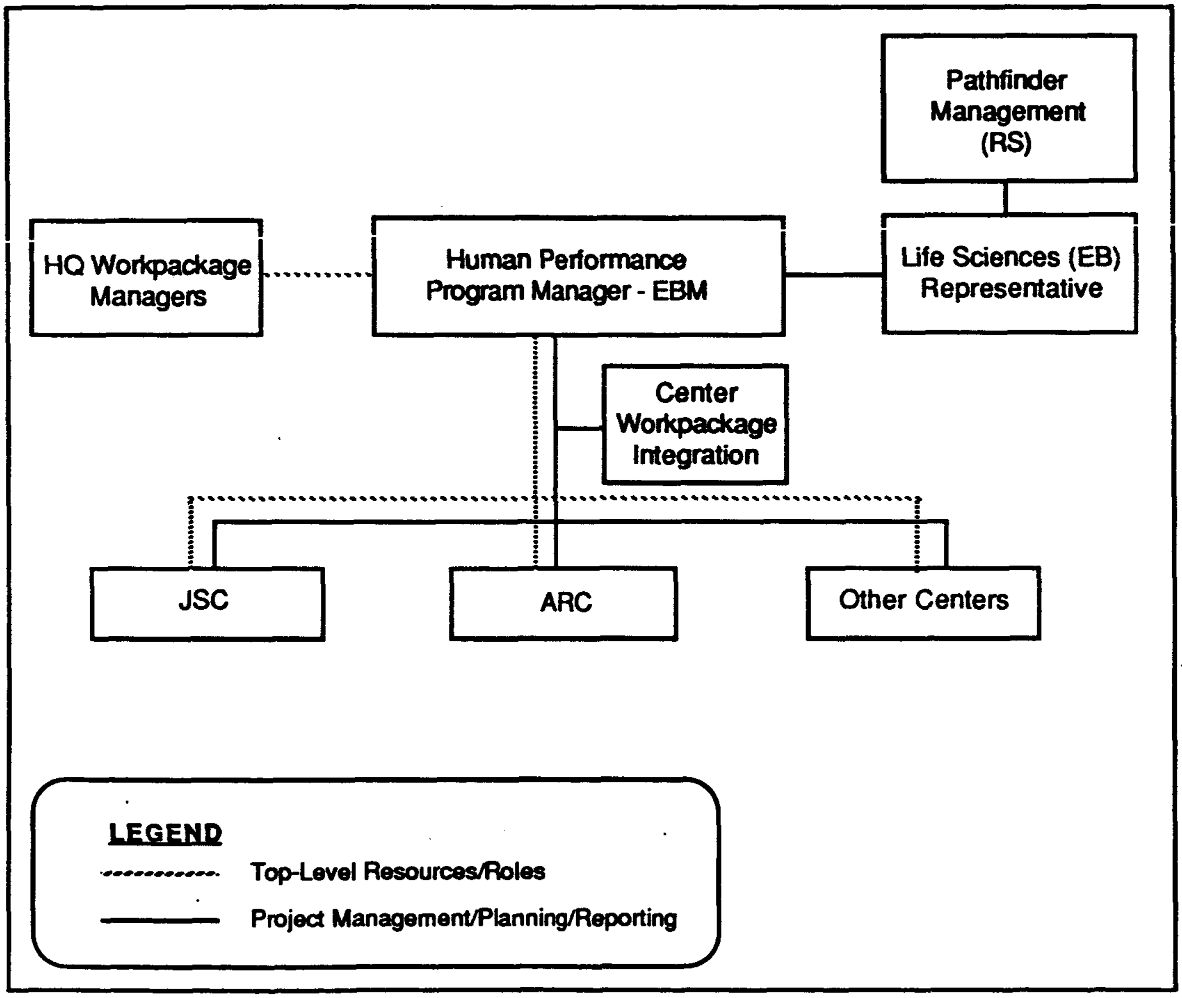

Figure 4.2 Pathfinder Human Performance Program Management Structure

The Human Performance Program Manager (Code EBM) will coordinate activities with those of the Bioregenerative Life Support Program Manager (Code EBR). The Life Sciences Pathfinder representative will coordinate activities between the Life Sciences Division (Code EB) and Pathfinder management (Code RS). The Life Sciences Pathfinder representative is also the Life Sciences-Office of Exploration liaison and will assume the responsibility of coordinating the evolving needs of the Office of Exploration (Code Z) with the Life Sciences-Pathfinder activities.

4.4 Program Coordination

The Human Performance Program is integrated with programs in Operational Medicine, Biomedical Research, Environmental Monitoring, Gravitational Biology, Biological Systems Research and their related flight components within the Life Sciences Division (Code EB) of OSSA. Coordination of the Human Performance Program and other elements of Humans-in-Space (Physical/Chemical Life Support, EVA/Suit, Space Human Factors Technology, Crew Protective Systems Technology) will be through the Pathfinder Program Manager.

The preparation for advanced space missions as represented by the Human Performance Program evolves from and builds on related life science activities. In all cases the existing Supporting Research and Technology (S, R & T) program will continue to provide baseline information from which advanced needs can be anticipated and studied. OAST will coordinate with Code EB in determining the performance characteristics, scope and schedule for technologies requiring development, and OSSA, with OAST participation, will develop human acceptance and human performance criteria for systems level testing and will validate test performance.

4.5 Program Planning and Documentation

A detailed Human Performance Project Plan will guide the five-year, technology development first phase of the effort. This plan will be developed over the next few months and maintained cooperatively among the participating NASA field Centers and the Life Sciences Division, OSSA. The Center with primary activity in an area will be responsible for coordinating and documenting that area activity, and the Life Sciences Division, NASA HQ will integrate areas and produce the final Project Plan document in conformance with this Program Plan. The authority to resolve conflicts will reside with the EB Human Performance Program Manager. The Technology Project Plan will determine program content, Center responsibilities, resource allocation, and milestones. The program will be formally reviewed each year and refined as appropriate to reflect research needs and funding availability. During this review, there will be an opportunity for each Center to participate within their particular areas of expertise, and the Project Plan will be modified as required. A Project Plan for Phase II of the program will be developed at the completion of Phase I.

4.6 Program Reporting

4.6.1 Quarterly Status Report

Program reporting documentation will consist of quarterly technology project reports, submitted by the Human Performance Program Manager to the Pathfinder Program Manager. These reports will track progress against milestones and schedules. These reports will also identify and track any problems and/or issues, as well as potential corrective actions.

4.6.2 Annual Report

An annual report will be prepared by the Human Performance Program Manager summarizing the year's accomplishments and progress toward achieving approved technology performance objectives. The annual report will also identify key activities for the next fiscal year and issues that could impact the long term goals and objectives of the Human Performance element.

4.7 Advisory Committees and Working Groups

Technical advice will be provided to the Human Performance Program Manager by NASA's Aerospace Medical Advisory Committee and by the Committee on Space Biology and Medicine of the National Research Council. Technical support to the program and to the element managers will be provided by the relevant Life Sciences Discipline Working Groups which include membership from the involved Centers. The Human Performance Program Manager will also participate in Life Sciences coordination activities that are being developed by the Associate Deputy Administrator (ADA). The nature and scope of these activities are under determination.

SECTION 5

TECHNICAL PLAN

5.1 Overview

The Human Performance element of Humans-in-Space, Project Pathfinder, will provide research and analysis in those areas of crew health, safety, and productivity that are needed to determine requirements for advanced missions. This research and analysis will be directed toward understanding the potential threats to the welfare and performance of crews and toward developing the appropriate requirements to address these threats.

The Human Performance Program technical plan is organized according the program work breakdown structure (WBS). It is divided into four major work packages that correspond to the three discipline areas of artificial gravity, radiation, and space human factors, with the fourth area concerned with the biomedical and performance issues of EVA.

Detailed contents of each work package will be provided in the Phase I Technology Project Plan. These include objectives, technical approach, description, schedule and milestones, deliverables, and resource allocations. Details regarding the overall technology performance objectives and technology readiness objectives are also contained the Technology Project Plan. The following section provides a brief description of each work package area including task areas and sub-elements.

5.2 Artificial Gravity

5.2.1 Description/Status

For humans raised in the 1-G field of earth, one of the most anamolous conditions of spaceflight is weightlessness. In its attempt to adapt to this novel environment, the body undergoes changes in the neurovestibular, cardiovascular, musculoskeletal, and in the hormonal and immune systems. Except for space sickness which affects about half of all space travellers and generally lasts about 2-3 days, weightlessness appears to be reasonably well tolerated over the short term. However, as time in weightlessness lengthens, it becomes increasingly important to exercise vigorously to offset the loss of muscle mass and to keep the heart active and healthy. However, calcium continues to be lost from the bones over the duration of the mission. It is believed that a calcium loss of about 25-30% would make the bones vulnerable to spontaneous fracture. It is also believed that a loss of this magnitude may not be fully recoverable after return to earth. In order to protect astronauts from a weakening of the various bodily systems, and to relieve them of the necessity of engaging in grueling daily exercise, artificial gravity has been proposed as the candidate countermeasure-of-choice on long-duration missions. At present no artificial gravity program exists. To date NASA has flown only relatively brief missions for which artificial gravity was not a requirement. The Soviets have flown much longer missions, but they are not currently concentrating work on artificial gravity. Although it is generally agreed that artificial gravity will be needed for very long misssions, it is not known whether artificial gravity must be experienced continuously or if brief and repeated exposure would suffice. Other questions concern the specifics of the artificial gravity system needed and possible negative side effects.

5.2.2 Work Package Tasks

The major tasks that will be performed as part of this work package element are:

1. Rotation Rate studies, including

   - threshold and tolerance rotation rates
   - human and animal studies
   - investigation of side effects (coriolis, cross-coupled stimulation)

2. Duration studies, including

   - required durations
   - human and animal studies

3. G-loading Studies, including

   - required G-magnitudes
   - human and animal studies
   - tradeoff studies between G-duration and G-magnitude

5.3 Radiation

5.3.1 Description/Status

The crewmembers of a piloted mission to Mars or a lunar base will be unavoidably exposed to ionizing radiation as they pass through the inner trapped proton belt, the outer trapped electron belt, and through the Galactic Cosmic Radiation (GCR) flux of interplanetary space. Moreover, outside of the Earth's magnetosphere, there is the possibility for exposure to proton radiation from Solar Particle Events (SPE's).

The dose equivalents and radiation health risk for piloted Mars or Lunar Base missions can be estimated, but these estimates are uncertain. Shielding calculations must be refined. Particle transport through absorbing material is a complex function of the particle fluence, the charge and energy (velocity) of the particles, the interaction of the primary particulate radiation with the spacecraft material and crewmembers' bodies, the production of secondary particles, body self-shielding, the ionization density or Linear Energy Transfer (LET) of the primary and secondary particles in tissue, Relative Biological Effectiveness (RBE) of different particles, and other factors.

For many of these factors the uncertainties are very large and must be reduced if NASA is to maintain ALARA (As Low As Reasonably Achievable) dose-equivalents. For short duration (less than 90 days) Earth orbital missions, there has been no problem in meeting ALARA. For Lunar or Mars missions, the dose equivalents could be an order or two higher than those previously experienced by any astronaut. Therefore, dosimetry that is adequate for Space Shuttle missions is not adequate for Moon-Mars missions. Moreover, sudden large changes in the solar particle flux may occur. And, in deep space, Galactic Cosmic Radiation is the prime source of biologically-damaging ionizing radiation. Other technologies must be developed and evaluated to ascertain if the depth-dose-equivalents and associated risks can be reasonably reduced. These include active dosimetry, solar particle event warning systems, etc.

5.3.2 Work Package Tasks

The major tasks that will be performed as part of this work package element are:

1. Dosimetry and effects studies, including
   - estimates of space radiation doses received by Moon/Mars mission astronauts
   - conversion to dose equivalents
   - assessment of radiocarcinogenic and other risks
   - establishment of methods for assessing, managing and advising concerning risk
2. Countermeasure studies, including
   - shielding requirements
   - improved forecasting and prediction
   - pharmaceuticals
   - selection

5.4 Space Human Factors

5.4.1 Description/Status

Future space-flight missions, such as a Lunar base or a Mars mission, will involve small groups of individuals living and working together effectively for extended periods in self-sufficient, isolated, confined, and high-risk environments. We have little direct experience with long-duration missions and no experience with missions involving a high level of crew autonomy. Experience in long-duration, isolated, confined and dangerous environments that are analogous to space has demonstrated that non-adaptive behavior can emerge. The characteristics of advanced missions will necessitate the development of new procedures, techniques and technologies to maintain and enhance crew safety, well being and productivity. Under long-duration and autonomous space-flight conditions, the environmental confines and the dynamics of crew interactions will pose significant challenges that must be better understood and managed before embarking on a mission of exploration.

The available empirical data on performance during microgravity and after returning to a gravity environment after a prolonged microgravity exposure is limited. Evaluations of technologies proposed to offset the physical effects of microgravity must also include performance measures.

Human operations in advanced and extended duration missions will require new understanding of skill and social mix. Questions of crew size and composition as well as workload and scheduling must also be examined in light of the demanding human requirements of exploration missions. Principles must be established to guide the implementation of human/automated systems from a health perspective (i.e., from the standpoint of physical well being, safety, and productivity.) Before implementing automated technologies, it is necessary to understand the tasks to be performed and the benefits and potential errors involved in various approaches to the allocation of tasks as between humans and machines, between the crew and the ground, and the implication of the communications and other technologies required to support these decisions.

5.4.2 Work Package Tasks

The major tasks that will be performed as part of this work package element are:

1. Habitability studies including volume requirements

2. Crew Factors studies including guidelines for crew composition, compatibility, chain of command, and communications

3. Human/machine studies including allocation of human and automated functions

4. Mission/operational task analysis

5. Performance studies in micro and artificial gravity

6. Establishment of an analog testbed

5.5 Extravehicular Activity (EVA)

5.5.1 Description/Status

Protecting the well being of astronauts before, during and following extravehicular activity is a continuing challenge of spaceflight. The demands of space station, especially as they involve assembly tasks, will significantly increase the time and workload associated with EVA as well as the potential threat to the safety of astronauts. However, EVA requirements for station, once achieved, will need to be further extended in order to meet the demands presented by missions of exploration.

Exploration missions will require that extravehicular activity be conducted at great distances from the support systems of Earth. Exploration missions will also involve a range of gravity conditions and a diversity of environments in which the astronaut must maneuver and work. In addition to issues of useability, durability and maintainabiliy of suits (which are under study through the Office of Aeronautics and Space Technology), relevant Life Science issues include prebreathing regimes; establishment and maintenance of the space suit and associated life support system; environmental, health and workload monitoring; requirements for radiation protection; productivity; pressurization and breathing strategies for emergency return to the habitat; etc. As we move towards longer and more distant missions, the time and energy spent on preparing for, executing, and recovering from EVA will become increasingly precious. This task is directed towards understanding the dynamics of the physical, physiological, and behavioral processes associated with extravehicular activity so that requirements can be established to safely reduce the time spent before and after EVA, while maximizing the ability of the astronaut to accomplish EVA tasks.

5.5.2 Work Package Tasks

The major tasks that will be performed as part of this work package element are:

1. Environmental and physiological studies including

    - establishnment of environmental requirements
    - establishment of medical protocols
    - guidelines for medical monitoring

2. Radiation studies including

    - risk assessment on advanced missions
    - warning systems and related protocols

3. Performance studies including

    - biomechanics and activity measurements
    - workload and scheduling requirements

5.6 Five-Year Planning Summary

5.6.1 Schedule

Assuming the resource allocations outlined in the following section, by the completion of Phase I, preliminary requirements will be in place to guide the development of technologies for artificial gravity, radiation, space human factors and EVA. In the area of artificial gravity, descriptions of the effects of intermittent centrifugation and chronic rotation on the various physiological systems will have been made and determinations of the strategies for use of artificial gravity will be in place. In the radiation area, improved mathematical models of the Galactic Cosmic Radiation and its effects at the organ level will be developed and new methods of assessing health risk identified. Approaches for improving the forecasting of Solar Particle Events will also be completed. In space human factors, preliminary requirements for crew organization and communication will be developed; mission analyses and preliminary habitability and human/machine guidelines will be assessed; and an analog testbed will be established. In EVA, preliminary physiological, environmental, and performance requirements for advanced systems will be established.

5.6.2 Milestones

Major milestones for the planned five-year, Phase I of the Pathfinder Human Performance Program are provided in Figure 5.1. Specific work package milestones will be outlined as part of the Project Plan.

HUMAN PERFORMANCE
5-YEAR MILESTONE SCHEDULE

SUBELEMENT	SCHEDULE/MILESTONE				
	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Artificial Gravity					
Initiate Artificial Gravity Research	Δ				
Phase A, Variable Gravity Research Facility			Δ———	———	———Δ
Interim Research Report			Δ		
Artificial Gravity Deliverables					Δ
Radiation					
Initiate Research	Δ				
GCR Deliverables					Δ
Interim Research Report			Δ		
SPE Deliverables					Δ
Space Human Factors					
Initiate Research	Δ				
Interim Research Report			Δ		
Space Human Factors Deliverables					Δ
EVA					
Initiate Research	Δ				
Interim Research Report			Δ		
Physiological and Environmental Deliverables					Δ
Performance Deliverables					Δ
Yearly Requests	Δ	Δ	Δ	Δ	
Quarterly Reports	Δ Δ	Δ Δ Δ	Δ Δ Δ	Δ Δ Δ	Δ Δ
Yearly Reports	Δ	Δ	Δ	Δ	
Final Report (Phase I)					Δ

FIGURE 5-1

5.5.7 Long-Range Program Plan and Options

During Phase II, the definition of all key Human Performance requirements will be completed. A close coordination will be maintained with OAST so that human health and performance requirements can be phased in as they become available. This coordination will be accomplished both formally by contact between the Code EB Pathfinder coordinator and the Pathfinder program manager, and informally by contact between the subelement program managers and individuals in OAST with responsibility for relevant technology development. The process of phasing in requirements as they become available will allow for technology development to proceed as the remaining requirements are established. The direction of the artificial gravity work will be influenced by decisions made by the Office of Exploration and commitments made at a national level, as well as by the results obtained in the Phase I research. Although the Variable Gravity Research Facility is not part of HiS/Pathfinder, the results of the artificial gravity research will be timed, as appropriate, to support Phase C/D of this activity. In the radiation area, studies during Phase II will emphasize on-board alarm systems, forecasting technologies, and materials protection, both in terms of transportation vehicles and construction of radiations shelters from Lunar and Martian materials. For space human factors, Phase II will allow the completion of training requirements and human/automation guidelines definition as well as the simulation and flight testing of facilities and protocols developed in the program. Phase II will see the development and maturation of requirements for extravehicular activity for advanced missions and the simulation of recommended procedures.

SECTION 6

RESOURCES AND FINANCIAL MANAGEMENT PLAN

A five-year budget projection for the Human Performance Program will be provided on a yearly basis by the Pathfinder Program Manager, Office of Aeronautics and Space Technology. The Human Performance Program Manager is responsible for distribution of the budget among work elements. Funding will be distributed and tracked according to the work breakdown structure which will be developed for the Project Plan.

Resource requirements, including both funding and NASA workforce, for FY 89 and for the remaining four years of Phase I are provided in Table 6.1. A preliminary estimate of funding levels required to support the Human Performance Program during Phase II is given in Table 6.2.

Details of the FY 1989 and four subsequent years of Phase I will be as shown in the Human Performance Project Plan, including funding and workforce allocations for the individual work packages.

RESOURCE REQUIREMENTS
HUMAN PERFORMANCE PROGRAM

RESOURCES	SCHEDULE (FISCAL YEAR)				
	1989	1990	1991	1992	1993
Funding ($,M)	2.125	2.2	9.0	11.0	13.0
NASA Workforce (WY/Year)	TBD	TBD	TBD	TBD	TBD

Table 6-1. PHASE-I

RESOURCES	SCHEDULE (FISCAL YEAR)				
	1994	1995	1996	1997	1998
Funding ($,M)	13.0	13.0	13.0	10.0	5.0
NASA Workforce (WY/Year)	TBD	TBD	TBD	TBD	TBD

Table 6-2. PHASE-II

SECTION 7

CONTRACTING STRATEGY AND PLANS

Details of Contracting plans and the distribution between in-house, university, and industry activities will be provided in the Human Performance Project Plan.

SECTION 8

FACILITIES STRATEGY AND PLANS

Details of facilities requirements will be provided in the Human Performance Project Plan. It is likely that some unique facilities, both at NASA Field Centers and elsewhere, will have to be upgraded, developed, or constructed in order to meet the needs of the planned Human Performance Program.